Deutsches Zentrum
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Institut für Physik der Atmosphäre

QUANTIFY

Trends in ozone concentration caused by emissions from fossil fuel combustion and natural sources

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Introduction

Background

Ozone changes have significant impact on climate

Enhanced NO_x emissions lead to an enhanced tropospheric ozone production

Spatial distribution of NO_x emissions and therewith ozone vertical profiles of several ozone sources differ

Ozone production depends on location of emission

Question

Which effect have NO_x emission from different sources on ozone concentration and climate from 1960 to 2020?

Requirements

This requires a climate model, which includes tropospheric and stratospheric ozone-chemistry. (Here: E39/C)

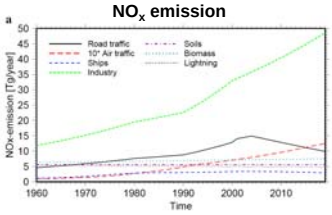
It requires methodologies to separate contributions to ozone changes: Tagging of NO_y and ozone from various sources (Grewe, 2004)

It requires reliable emission data sets for past and future.

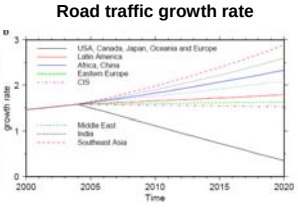
Climate-Chemistry Model E39/C

- **Ensemble simulation from 1960 to 2020.**
- **External forcings: sea-surface temperatures, greenhouse gases, emissions, QBO, volcanoes, solar cycle, and CFCs.**
- **Road traffic NO_x emissions**:
  Increased proportionally with industry until 2004. Since 2004 the increase of road traffic emissions is proportional to industrial emissions only in developing regions and decrease elsewhere.

NO_x emission



Road traffic growth rate



Ozone Production

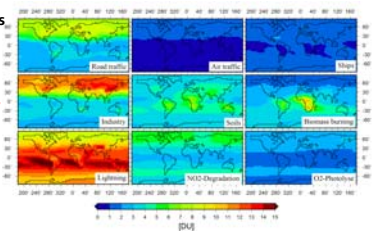
Ozone production efficiency (OPE) is dependent on altitude and location of emission:

NO_x emissions in higher altitudes produces more ozone than in lower altitudes due to enhanced solar radiation (e.g. lightning)

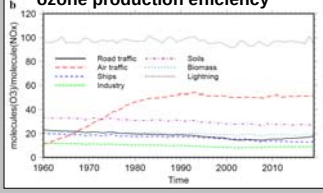
OPE in remote regions is higher than in polluted regions (e.g. soils)

Ozone changes similar to NO_x emission changes

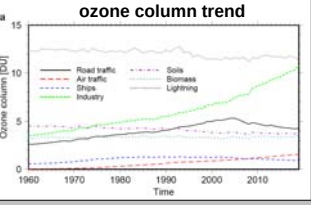
ozone column



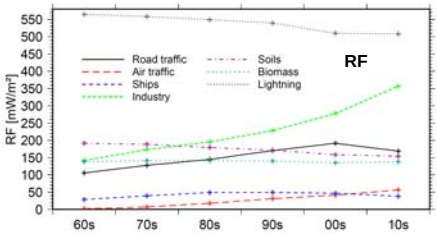
ozone production efficiency



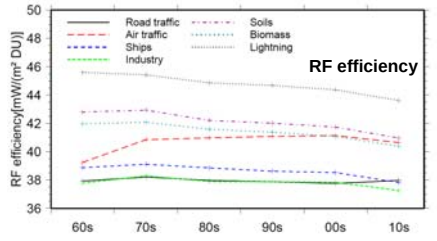
ozone column trend



Evolution of Ozone Radiative Forcing



Temporal correlation between RF und ozone column is rather close for each component

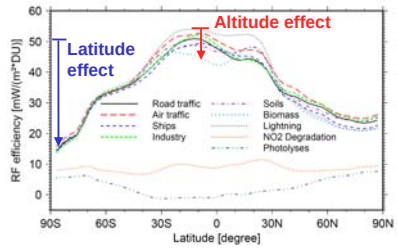


High RF efficiency: lightning

Intermediate RF efficiency: air traffic, soils and biomass burning

low RF efficiency: ships, road traffic and industry

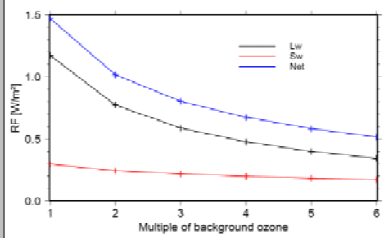
Evolution of Ozone Radiative Forcing



Altitude effect:
Dependency of green-house effect on the temperature of the absorber.

Latitude effect:
Longwave emission ~T_s^4, temperature difference at higher temperatures produces larger greenhouse effect than at lower temperatures

Saturation effect



Increasing ozone background leads to decreasing RF efficiency of almost all sources since 1980, which causes a saturation effect

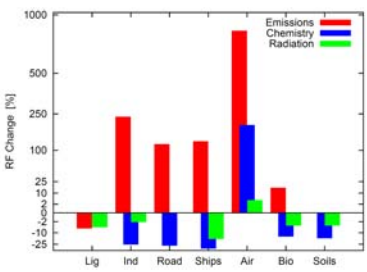
Summary

- **Ensemble climate-chemistry simulation performed for 1960 to 2020.**
- **Ozone Production Efficiency and RF efficiency depends on emission altitude and location: Large for lightning / Small for industry**
- **Trends in RF from various NO_x sources are controlled by their emissions**
- **RF changes are slightly decreasing due to:**

a changing atmospheric composition (beside aircraft)

RF saturation

What causes the trend in RF-Ozone?



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